Reply on comments of Dr. C. Cimarelli

Interactive comment on "Lightning and electrical activity during the Shiveluch volcano eruption on 16 November 2014" by B. M. Shevtsov et al.

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The manuscript presents a analysis of electrical activity detected by the WWLLN on 16 November 2014, which is related by the authors to the explosive eruption activity of Shiveluch volcano, Kamchatka occurring during that time. The authors make use of meteorological, seismological and satellite data to correlate the electrical activity to the onset of the eruption at Shiveluch and the following evolution stages of the ash plume and ash cloud. The work presented is surely valuable and present further evidence of electric activity generated by volcanic plumes. Given the growing number of observations of this phenomena and the many questions still open on the interpretation of such phenomena and related geophysical and volcanological observations, I strongly support the publication of this work. However I think the manuscript at this stage is

not yet ready for publication and needs a major revision in terms of structure and form data are presented (including usage of english), technical terminology used and interpretation of data. Here follow some general comments to the manuscript while specific comments and corrections are attached in the annotated manuscript file.
The manuscript is quite concise, which usually is a good thing, in this case however it seems that some more paragraph would add to the clarity of the paper, this is particularly true for what concerns the introduction and the section with discussion and interpretation of data. I encourage the authors of adding some more lines in the introduction to introduce more appropriately the aim of their work in light of the previous relevant works done by other authors on the topic.
Thomas, R.J., McNutt, S.R., Krehbiel, P., Rison, W., Aulich, G., Edens, H., Tytgat, G., and Clark, E., (2010) Lightning and electrical activity during the eruptions of Augustine volcano, in Power, J.A., et al., eds., The 2006 eruption of Augustine Volcano, Alaska: U.S. Geological Survey Professional Paper 1769-25, p. 579–608. Bennett, A.J., Odams, P., Edwards, D., and Arason, P., (2010), Monitoring of lightning from the April-May 2010 Eyjafjallajökull volcanic eruption using a very low frequency lightning location network: Environmental Research Letters, v. 5, 044013, doi:10.1088/1748-9326/5/4/044013. Behnke, S.A., McNutt, S.R., (2014). Using lightning observations as a volcanic eruption monitoring tool. Bulletin of Volcanology 76.
The terminology used to describe the volcano phenomenology is inappropriate. I understand the authors are not volcanologists therefore I have made some corrections in the text.
In particular the authors often refer to "ash fragmentation" when referring to the initial stages of the eruption. Ash is already a product of magma fragmentation. The fragmentation process usually happens within the volcanic conduit. Several experimental studies have investigated the occurrence of electrical discharges by fragmentation of magma/pyroclasts (fracto-electrification) and by rubbing/collision (tribo-electrification) of volcanic particles ejected during an eruption. It is still unclear to which extent these two processes contribute to the electrification of the volcanic plume and how much

overlap there is between the two. I invite the authors to read this recent literature and add few lines of discussion about experimental constraints on the mechanisms of ash charging in the introduction to better discuss advantages and limitations of their methodology: Cimarelli, C., Alatorre-Ibarguengoitia, M.A., Kueppers, U., Scheu, B., Dingwell, D.B., (2014) Experimental generation of volcanic lightning. Geology 42, 79-82. James, M.R., Lane, S.J., and Gilbert, J.S., (2000), Volcanic plume electrification: Experimental investigation of a fracture-charging mechanism: Journal of Geophysical

Research, v. 105, p. 16641–16649, doi:10.1029/2000JB900068. Méndez-Harper, J., Dufek, J., McAdams, J., (2015) The Electrification of Volcanic Particles during the Brittle Fragmentation of the Magma Column. Proc. ESA Annual Meeting on Electrostatics Houghton, I. M. P., K. L. Aplin, and K. A. Nicoll (2013), Triboelectric charging of volcanic ash from the 2011 Grimsvötn eruption, Phys. Rev. Lett., 111, 118501, doi:10.1103/PhysRevLett.111.118501

Least I would like to open a terminology polemic and to read the numerous references.
Let's agree what we discuss: a vent (blow), thermal upwelling of ash (which is named a plume) or a drift of ash clouds in a buoyancy mode.
The vent which is accompanied by a fragmentation of magma and vent lightnings, is not considered, because the time of the first lightning is 1 minutes 21 seconds. Plus the travel time of a seismic signal about 5 seconds. This is very long time for a vent stage.
We suppose that three first lightnings were plume lightnings. May be, and other are same.
The upwelling of ash in gravity field is accompanied by differentiation (separation) on size and fragmentation of ash. Heavy fractions of ash drop out from a cloud on the earth.
This can be considered as an early stage of cloud formation.
Least I would like to discuss the dynamic process of particles and charge separation in the clouds.
Our paper is the draft report on the results of eruption observation. One of the system which was used is WWLLN. May be, it will be useful for somebody. This is the aim of our work.

As a general comment, WWLLN detects only cloud-to-ground lightning and we know from direct observations that volcanic plume often produce numerous intra-cloud lightning. The efficiency of WWLLN in detecting volcanic lightning is hence relatively low compared to other detection systems/arrays (see Behnke and McNutt, 2014 for a review).

WWLLN is arranged as well as any other system of lightning detection. On the long distances from the discharge, strong cloud-ground lightnings are detected only. This is the wave propagation effect, but not WWLLN features. If WWLLN stations is installed on the small distances, the rich information of lightning process will be obtained.
The WWLLN are used restrictedly now. We show, how even in this case, WWLLN can be useful for volcanology. WWLLN allows to see the electricity activity of volcano anywhere in the world on certain level of sensitivity.
There are many opportunities of WWLLN development: optimum placing, improving of time accuracy recorder, using of both polarizations, analysis of signal form features and other.
There are many other systems to obtain detailed information.

Another thing that is not really discussed in the paper is the position and timing of the flashes detected by the WWLLN with respect to the plume direction and progressive drifting to the SW. It seems from the figures 1 and 3 that lightning activity has been going on up-wind respect to the plume (I am not sure this is what the authors want to say at line 9 in section 3). A scale and some more reference points in figure 3 would greatly help.

It is not clearly told and will be deleted. According to fig. 2, a wind changed a direction with altitude that complicated the lightning locations.

I tried to gather as much information I could about this eruption of Shiveluch and really didn't find much. There are anyways some source of information I would recommend the authors to check to implement their analysis (see also comments in the annotated manuscript): VAAC Tokyo:

http://ds.data.jma.go.jp/svd/vaac/data/# Kamchatka Volcanic Eruption Response Team: http://www.kscnet.ru/ivs/kvert/index_eng.php Smithsonian Institution Global Volcanism Program: http://volcano.si.edu/volcano.cfm?vn=300270
As for what concerns the presentation quality of the paper I would suggest the authors to ask english native speaking colleagues to check the manuscript before resubmission, I am not a native speaker either and I know how crucial can be to rightly convey concepts making use of the right words. From my side I already suggested some modification

in the annotated manuscript. Please also double check the reference list since many of the paper in the reference have not been cited in the text.
I would invite anybody who have more information on this eruption to post it as a comment to this manuscript to help the authors.
Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/3/C2488/2015/nhessd-3-C2488-2015-supplement.zip
Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 6745, 2015.

Thank you for discussion and annotated manuscript!

With allowance for comments, the paper will be improved and corrected in English by one of the coauthor Prof. R.H. Holzworth.